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Search for natural Supersymmetry in events with 1 b-tagged jet using razor
variables at $\sqrt{s} = 8$ TeV

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ABSTRACT

We discuss a search for natural Supersymmetry in events with at least one bottom-quark jet using razor variables in proton-proton collisions at $\sqrt{s} = 8$ TeV with the CMS detector. The event distribution in the plane defined by the razor variables R^2 and M_R is studied, searching for a peaking signal on top of a smoothly falling standard model background. The data are consistent with the expected background, modeled by a template function. The 95% C.L. exclusion limit on the masses of the gluino and lightest supersymmetric particle in a benchmark simplified model are presented. For a lightest supersymmetric particle mass of 100 GeV, the pair production of gluinos in a multi-bottom final state is excluded for gluino masses up to 1375 GeV.

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1 Introduction

R-parity conserving, weak-scale supersymmetry (SUSY) is a well-motivated theory, which provides a suitable dark matter candidate and predicts events at the LHC with jets and large missing transverse momentum E_T^{miss} . Natural SUSY models contain a light chargino $\tilde{\chi}^\pm$ and a neutralino $\tilde{\chi}^0$ nearly degenerate in mass, a light top or a bottom squark (\tilde{t} or \tilde{b}), and potentially a slightly heavier gluino \tilde{g} in order to minimize the fine-tuning associated with the observed value of the Higgs boson mass.

We discuss a search for squarks and gluinos in the context of natural SUSY spectra, performed on events with two or more jets, at least one of which is identified as originating from a bottom quark [1, 2]. The search is carried out on the data collected by the Compact Muon Solenoid (CMS) Collaboration in proton-proton collisions at $\sqrt{s} = 8$ TeV in 2012, corresponding to an integrated luminosity of 19.3 fb^{-1} . A complete description of the CMS detector is given in [3]. We utilize the razor kinematic variables R^2 and M_R [4, 5] to search for a broadly peaking signal on the smoothly falling standard model (SM) background. The analysis is performed in several disjoint datasets (referred to as *boxes*), differing in the lepton and the jet multiplicity. In the following, we discuss the results relating to the zero-lepton boxes, which are analyzed in exclusive b-tagged jet multiplicity bins, to maximize the sensitivity to direct and cascade production of third generation squarks. This search extends a previous analysis by CMS, performed with the same technique on the data collected at a center-of-mass energy of 7 TeV [6, 7].

2 Razor variables and event selection

In the canonical two-jet topology resulting from the production of two squarks each decaying to a quark and the lightest SUSY particle (LSP), the razor variables M_R and R^2 are intended to characterize the mass scale of the of SUSY particles and the transverse momentum imbalance of the events. The four-momenta of the two jets as well as the missing transverse momentum \vec{E}_T^{miss} may be used to compute M_R and R^2 , defined as

$$M_R \equiv \sqrt{(|\vec{p}_{j1}| + |\vec{p}_{j2}|)^2 - (p_z^{j1} + p_z^{j2})^2} \quad (1)$$

$$R^2 \equiv \frac{E_T^{\text{miss}}(p_T^{j1} + p_T^{j2}) - \vec{E}_T^{\text{miss}} \cdot (\vec{p}_T^{j1} + \vec{p}_T^{j2})}{4M_R^2} \quad (2)$$

where \vec{p}_{ji} , \vec{p}_T^{ji} , and p_z^{ji} are the momentum of the i th-jet, its transverse component, its longitudinal component, respectively, while E_T^{miss} and p_T^{ji} are the magnitude of \vec{E}_T^{miss} and \vec{p}_T^{ji} , respectively.

The search for SUSY is carried out on the events selected by a set of criteria summarized in Table 1. The events are detected by a set of dedicated triggers, consisting of a loose selection on M_R and R^2 . The events are also required to satisfy a requirement of two jets in the central part of the detector. The trigger efficiency is measured to be $(95 \pm 5)\%$.

Jets are reconstructed by clustering the Particle Flow (PF) [10, 11] candidates with the FASTJET [13] implementation of the anti- k_T algorithm [14] with the jet size set to $R = 0.5$. We select events containing at least two jets with $p_T > 80$ GeV and $|\eta| < 2.4$. For each event, the \vec{E}_T^{miss} and the four-momenta of all the jets with $p_T > 40$ GeV and $|\eta| < 2.4$ are used to compute the razor variables.

The medium working point of the combined secondary vertex algorithm [9] is used for jet b-tagging. Events without at least one b-tagged jet are discarded, a criterion motivated by the expectation of a light top or bottom squark accessible at LHC from naturalness considerations. A tighter requirement (≥ 2 b-tagged jets) is imposed on events with less than four jets to reduce the $Z(\rightarrow \nu\bar{\nu})$ +jets background to a negligible level.

3 Modeling the standard model backgrounds

Under the hypothesis of no contribution from new physics processes, the event distribution in the (M_R, R^2) plane can be described by the sum of the weak vector boson plus jets production (V+jets where V =

Requirements				
Box	lepton	b-tag	kinematic	jet
MultiJet	none	≥ 1 b-tag	$(M_R > 400 \text{ GeV and } R^2 > 0.25) \text{ and } (M_R > 450 \text{ GeV or } R^2 > 0.3)$	≥ 4 jets
2b-tagged jet	none	≥ 2 b-tag	$(M_R > 400 \text{ GeV and } R^2 > 0.25) \text{ and } (M_R > 450 \text{ GeV or } R^2 > 0.3)$	2 or 3 jets

Table 1: Kinematic and multiplicity requirements defining the two zero-lepton razor boxes.

W, Z) and the top quark-antiquark and the top single-quark production, generically referred to as the $t\bar{t}$ contribution.

Based on the study of the data collected at $\sqrt{s} = 7$ TeV and the corresponding MC samples [6, 7], the two-dimensional probability density function $P_{\text{SM}}(M_R, R^2)$ of each SM process is found to be well described by the template function:

$$f(M_R, R^2) = [b(M_R - M_R^0)^{1/n}(R^2 - R_0^2)^{1/n} - 1]e^{-bn(M_R - M_R^0)^{1/n}(R^2 - R_0^2)^{1/n}}. \quad (3)$$

where b , n , M_R^0 , and R_0^2 are free parameters of the background model. The shape of the template function is determined through an extended maximum likelihood (ML) fit to the data. The template function is found to adequately describe the standard model background in each of the boxes, for each b-tagged jet multiplicity.

The background shape parameters are estimated from the events in two sidebands at low M_R ($M_R < 550$) and at low R^2 ($R^2 < 0.3$). This shape is then used to derive the background prediction in the signal-sensitive region along with a systematic uncertainty associated to the background shape. Figure 1 illustrates the agreement between the observation and the background prediction in the MultiJet box. No significant deviation is observed.

4 Interpretation and conclusions

An interpretation of the results in a representative SUSY simplified model is shown in Figure 2. The model topology consists of gluino pair-production, in which each gluino decays to a bottom quark, a bottom antiquark and a LSP. Events for this SUSY simplified model are generated with the MADGRAPH v5 simulation [15], while the SUSY particles are decayed and the event is showered in the PYTHIA v6 simulation code [16], before being processed through a fast simulation of the CMS detector [12]. The SUSY particle production cross sections are calculated to next-to-leading order (NLO) and next-to-leading-logarithm (NLL) accuracy [17, 18, 19, 20, 21], assuming the decoupling of the other SUSY partners. The NLO+NLL cross section and the associated theoretical uncertainty [22] are taken as a reference to derive exclusion limits on SUSY particle masses.

We carried out a search for supersymmetric particles using proton-proton collision data collected by CMS at $\sqrt{s} = 8$ TeV. The dataset size corresponds to an integrated luminosity of 19.3 fb^{-1} . We analyzed events with at least two jets, at least one of which is identified as a b-tagged jet, and study the event distribution in the (M_R, R^2) plane. No significant excess was observed over the standard model background expectations, derived from a fit to the data distribution in low- M_R and low- R^2 sidebands. The search results were translated into at 95% confidence level exclusion limits on the masses of the gluino and the LSP, in the context of a simplified natural SUSY model. For a LSP mass of 100 GeV, the pair production of gluinos in a multi-bottom final state was excluded for gluino masses up to 1375 GeV.

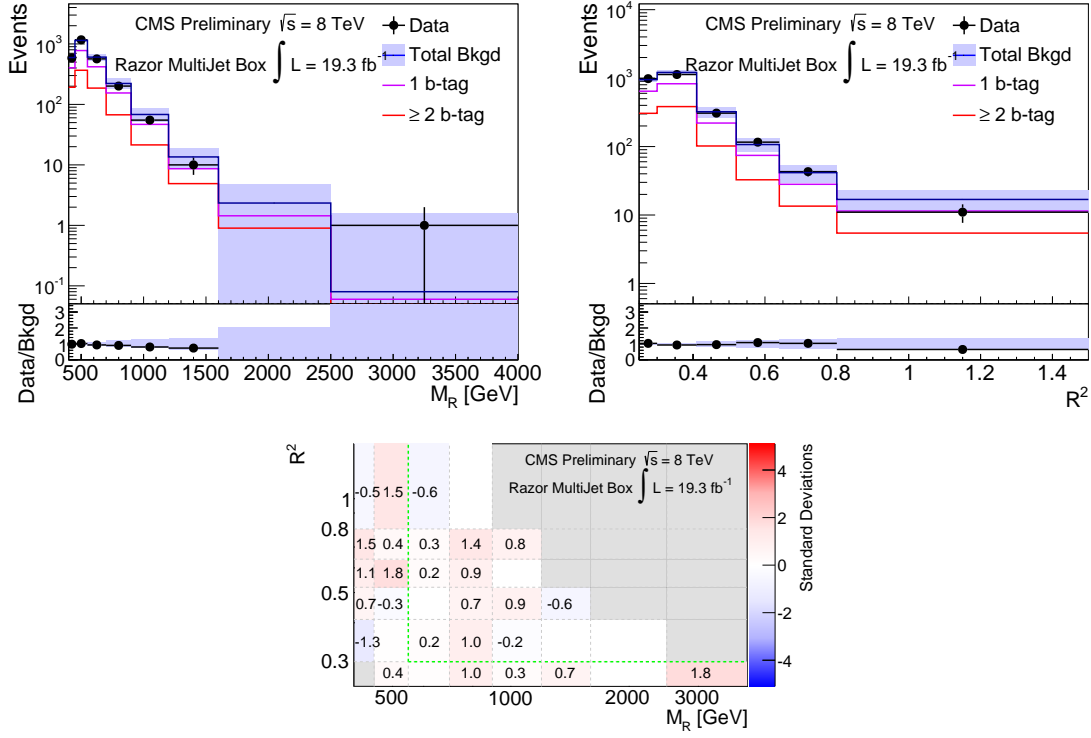


Figure 1: (Left and middle) Projection of the sideband fit result in the MultiJet box on M_R and R^2 , respectively. The solid line and the filled band represent the total background prediction and its uncertainty. The points and the band in the bottom panel represent the data-to-prediction ratio and the prediction uncertainty, respectively. (Right) Comparison of the expected background and the observed yield in the MultiJet box. A two-sided p-value (translated into the corresponding number of standard deviations) is computed comparing the observed yield to the distribution of expected background yields.

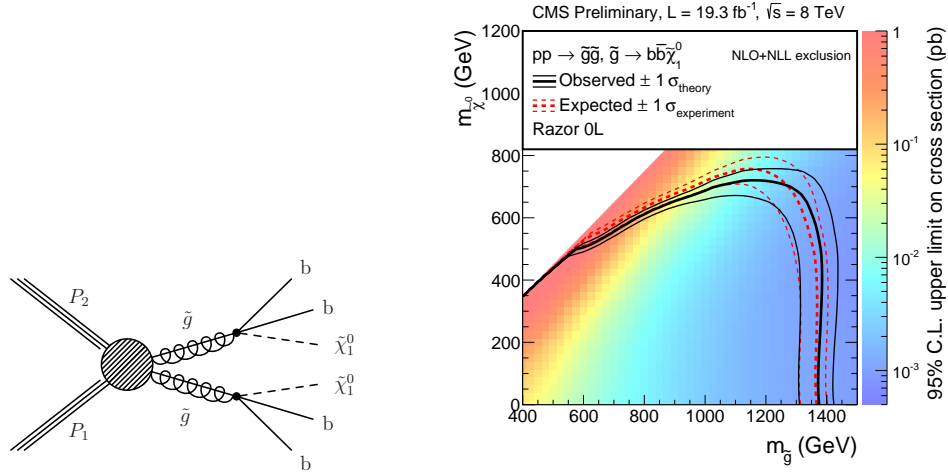


Figure 2: (Left) A diagram displaying the event topology of a gluino-mediated SUSY model in the multi-bottom final state. (Right) Interpretation of the inclusive search with razor variables in the context of a gluino-mediated model. The color coding denotes the observed 95% CL upper limit on the SUSY signal cross section. The dashed and solid lines represent the expected and observed exclusion contours at 95% CL, respectively.

References

- [1] S. Chatrchyan *et al.* [CMS Collaboration], CMS-PAS-SUS-13-004
- [2] S. Chatrchyan *et al.* [CMS Collaboration], CMS-PAS-SUS-14-011
- [3] S. Chatrchyan *et al.* [CMS Collaboration], JINST **3**, S08004 (2008).
- [4] C. Rogan, arXiv:1006.2727 [hep-ph].
- [5] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Rev. D **85**, 012004 (2012) [arXiv:1107.1279 [hep-ex]].
- [6] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Rev. Lett. **111**, no. 8, 081802 (2013)
- [7] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1405.3961 [hep-ex].
- [8] W. Verkerke, *et al.*, arXiv:physics/0306116
- [9] S. Chatrchyan *et al.* [CMS Collaboration], CMS-PAS-BTV-13-001
- [10] S. Chatrchyan *et al.* [CMS Collaboration], CMS-PAS-PFT-09-001
- [11] S. Chatrchyan *et al.* [CMS Collaboration], CMS-PAS-PFT-10-011
- [12] S. Chatrchyan *et al.* [CMS Collaboration], CMS-DP-2010-03
- [13] M. Cacciari *et al.*, Eur. Phys. J. C **72**, 1896 (2012) [arXiv:1111.6097 [hep-ph]].
- [14] M. Cacciari *et al.*, JHEP **0804**, 063 (2008) [arXiv:0802.1189 [hep-ph]].
- [15] J. Alwall *et al.*, JHEP **1407**, 079 (2014) [arXiv:1405.0301 [hep-ph]].
- [16] S. Hoeche *et al.*, hep-ph/0602031.
- [17] W. Beenakker *et al.*, Nucl. Phys. B **492**, 51 (1997) [hep-ph/9610490].
- [18] A. Kulesza *et al.*, Phys. Rev. Lett. **102**, 111802 (2009) [arXiv:0807.2405 [hep-ph]].
- [19] A. Kulesza *et al.*, Phys. Rev. D **80**, 095004 (2009) [arXiv:0905.4749 [hep-ph]].
- [20] W. Beenakker *et al.*, JHEP **0912**, 041 (2009) [arXiv:0909.4418 [hep-ph]].
- [21] W. Beenakker *et al.*, Int. J. Mod. Phys. A **26**, 2637 (2011) [arXiv:1105.1110 [hep-ph]].
- [22] M. Kramer *et al.*, arXiv:1206.2892 [hep-ph].